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NEUROPROSTHETICS

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Abstract

Neuroprosthetics are implantable devices designed to replace or improve the function of a certain aspect of the central nervous system. The most famous and widely-used neuroprosthetic is the cochlear implant, which bypasses the eardrum and directly stimulates the human auditory nerve, giving the power of hearing to those who lack it. The first cochlear implant was built in 1957, and today, these implants are used by over 100,000 people.

Introduction

Neuroprosthetics (also called neural prosthetics) is a discipline related to neuroscience and biomedical engineering concerned with developing neural prostheses. Neural prostheses are a series of devices that can substitute a motor, sensory or cognitive modality that might have been damaged as a result of an injury or a disease. An example of such devices is Cochlear implants. This device substitutes the functions performed by the ear drum, Stapes, frequency analysis in the cochlea and stimulates the auditory nerves directly. A microphone on an external unit gathers the sound and processes it, the processed signal is then transferred to an implanted unit that stimulates the auditory nerves through a microelectrode array.

The development of such devices has a profound impact on the quality of human life, and research in this field intends to resolve disabilities.

There is another side to the application of neural prostheses. These implantable devices can also be used in animal experiments as a tool for neuroscientists in order to develop a better understanding of how the brain works. Wireless neuro recording from the brain of awake, freely behaving animals can open

many important doors into understanding how the brain handles different functions. Accurately probing and recording the electrical signals in the brain would help better understand the relationship among a local population of neurons that are responsible for a specific function. In order to substitute sensory, motor or cognitive modalities, we need to first understand which part of the brain is responsible for those modalities and how those functions are performed. Neuro prosthetics and neuro science have a very intertwined relationship. Neuro prostheses contribute to better understanding of the neural system and this better understanding helps develop better, more application-specific neural prostheses.

In order to achieve these devices there are many challenges. Any implanted device has to be very small in order to be minimally invasive, especially in the brain, eye, cochlea. Also this implant would have to communicate with the outside world wirelessly. Having wires sticking out of the head, eye, etc is not an option. Besides the discomfort and restrictions it would impose on the subject this could lead to infection in the tissue. This bidirectional wireless communication requires a high bandwidth for real-time data transmission; this is a great challenge considering that this data link has to operate

through the skin. The minimal size of the implant means no battery can be embedded in the implant, the implant works on wireless power transmission through the skin which is equally challenging as the data transmission. The tissue surrounding the implant is usually very sensitive to temperature rise so the implant must have very low power consumption in order to assure it won't harm the tissue. Another very important issue is the bio compatibility of the material that the implants are coated with. The more biocompatible these materials are the less tissue reaction they will cause thus resulting less implant risk and longer implant period.

Gradually as these devices become safer and the our understanding of how the brain works enhances the use of these devices will become more and more common and help people with severe disabilities live a normal life. The neuroprosthetic seeing the most widespread use is the cochlear implant, with approximately 100,000 in use worldwide as of 2006.

Today, the use of cochlear implants and pacemakers has become an undeniable fact of life. The future holds an exciting prospect for the every day use of a variety of neural prostheses

There are three main types of neuroprosthetics - sensory prosthetics, motor prosthetics, and cognitive prosthetics. Sensory prosthetics get information into sensory areas like hearing and sight, motor prosthetics help regulate or stimulate malfunctioning motor functions, and cognitive prosthetics are a largely still-on-the-drawing board field of future prosthetics for replacing or improving problem areas in the brain itself. Although the term "neuro" makes us think of the brain, all neuroprosthetics in use today replace nervous system aspects external to the brain.

Research in visual neuroprosthetics has given rise to extremely fine electrodes, thinner than a human hair. This has helped progress

tangential areas of neurophysiology, but unfortunately true visual prostheses - devices which would allow the blind to see - are still in development. Scientists have observed that selective stimulation of the visual cortex allows subjects to see phosphenes - the little glowing blurs you see when you rub your eyes - in pre-determined areas of the visual field. Research has produced visual prostheses that give patients fuzzy vision with pixel resolution of about 20 x 20, but these are just experimental and not ready for mass use.

In the area of motor neuroprosthetics, there is the well-known pacemaker, which stimulates the heart to beat when the natural cluster of pacemaker cells is having problems. Bladder control neuroprosthetics have helped patients with paraplegia due to spinal cord damage. Motor neuroprosthetics for the conscious control of movement have gotten some press in recent years. Patients who are totally paralyzed can be given these implants, which allow them to control a computer mouse for spelling out messages, playing games, or surfing the web. For someone who is otherwise locked in an unresponsive body, these implants can radically improve quality of life.

Neuroprosthetics is an area of intense scientific and clinical interest and rapid progress. Since the introduction of the cardiac pacemaker in 1932, we have seen developments that include cochlear prostheses, techniques for bladder and bowel control, deep brain stimulation, and restoration of mobility and respiration to paralyzed individuals.

History

Research was undertaken by the American CIA in the 1950s as one aspect of the MKULTRA designator, and was mostly related to aspects of mind control.

An early difficulty in the development of neuroprosthetics was reliably locating the electrodes in the brain; originally done by

inserting the electrodes with needles and breaking off the needles at the desired depth. More recent systems have included more advanced probes, such as those used in deep brain stimulation to alleviate the symptoms of Parkinsons Disease. The problem with either approach is that the brain floats free in the skull while the probe does not, and relatively minor impacts, such as a low speed car accident, are potentially damaging. Some researchers, such as Kensall Wise at the University of Michigan, have proposed tethering electrodes to be mounted on the exterior surface of the brain to the inner surface of the skull. However, even if successful, 'tethering' would not resolve the problem in devices meant to be inserted deep into the brain, such as in the case of deep brain stimulation.

Current research

Visual prosthesis

One of the prominent goals in neuroprosthetics is a visual supplement, noting roughly 95% of all people considered 'blind' suffer significant impairment but have some capability (for example, seeing some sort of blur) - only about 5% of 'blind' people are totally blind. By the 1940s, researchers had established the concept of artificial electrical stimulation of the visual cortex, and in the late 1960s, British scientist Giles Brindley produced breakthrough findings with a system for placing electrodes on the brain's surface. When specific areas of the brain were stimulated in blind volunteers, all reported "seeing" phosphenes that corresponded to where they would have appeared in space. However, experiments were discontinued because of the uncomfortably high currents required for stimulation on the surface of the brain.

Encouraged by this work, the National Institutes of Health undertook a project to develop and deploy an interface based on ultrafine wire (25 to 50 micrometres) densely populated with electrode sites that could be

implanted deep into the visual cortex, thus requiring less current than Brindley's original design. This work led to new electrode technology? Finer than the width of human hair? That could be safely implanted in animals to electrically stimulate, and passively record, electrical activity in the brain. The efforts produced significant advances in neurophysiology, with publication of hundreds of papers in which researchers attempted to develop an electronic interface to the brain.

With this new technology, several scientists, including Karin Moxon at Drexel, John Chapin at SUNY, and Miguel Nicolelis at Duke University, started research on the design of a sophisticated visual prosthesis. Other scientists have disagreed with the focus of their research, arguing that the basic research and design of the densely populated microscopic wire was not sophisticated enough to proceed.

Other prostheses

In 2003 Patrick Kennedy (Emory and Georgia Tech) had an operable if somewhat primitive system designed, allowing a handicapped person to spell words with nerve impulses.

Much of the ongoing research in neuroprosthetics concerns retinal implants and cochlear implants, though for example at the University of Southern California research is done for hippocampal implants.

Keywords

1. Cochlear implants
2. Computer
3. Pacemaker
4. Electrodes
5. Neuroscience

Conclusion

Research into neuroprosthetics is an ongoing and cutting-edge area of science. We should expect to see many more developments in the future, some of which will challenge common

assumptions about the interface between the mind and machines.

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